

OUTLINES
OF THE HALF-COURSE IN
NATURAL HISTORY 4,
WITH REFERENCES TO
DANA'S MANUAL OF GEOLOGY,
AND NOTES.

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WM. H. WHEELER, PUBLISHER.
1885.

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History



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OUTLINES OF NATURAL HISTORY 4.

INTRODUCTORY.

The Earth.

HOW REGARDED. *Dana, pp. 1-2.*

Earth is to be treated as a mechanism which has a history ; as a theatre (1) of the application of force, (2) of the development of life. It is as truly as is the steam-engine, a mechanism which is applying solar force.

Kepler's idea of the earth as a living, breathing creature is nearer right, than that of an utterly inanimate mass.

RELATION TO UNIVERSE. *Dana, p. 3. Planets*

Three proofs of Earth's kinship to ~~plants~~ *plants* :—

- (1) Telescopic—spherical form, continents and volcanos.
- (2) Meteoric—elements and laws of crystallography same.
- (3) Spectroscopic—elements of sun, etc., same as those of earth.

AIM OF GEOLOGY. *Dana, pp. 4-6.*

I. PHYSIOGRAPHIC GEOLOGY.

Earth's Contour and Surface Divisions.

ITS FORM. *Dana, p. 9.*

Flattening of earth is correlated with its rotation, being just what would result from earth's present angular velocity in a liquid globe of same size and density. This gives proof of the present or former molten state of the earth.

LAND AND WATER. *Dana, pp. 10, 13.*

From the cooling and development of an original nebulous mass, there results a solid surrounded by two oceans, of water and air, respectively. Much depends on the interaction of these two oceans, one partially, the other entirely covering the earth's surface. We see on surface of globe a great land-mass about No. Pole from which three triangles project southward into mass of water about So. Pole. Note that oceans keep practically same level, while lands rise and fall. Two great geologic forces are constantly at work on land, those above and at sea-level being acted on by *erosion*, the destructive force, and those below sea-level being subjected to *deposition*, the constructive force.

DEPTH OF OCEANS. *Dana, pp. 11, 12.*

Note that this is on the average much greater than the elevation of land-masses.

SURFACE RELIEFS. *Dana, pp. 15-23.*

Substitute for definition of *mountain*, as follows:— *A mountain* is a ridge of the earth's surface in which at least a part of the relief is due to the folding of strata.

A hill is a relief caused by the cutting away of parts of strata by erosive action, leaving remainder as an elevation.

A volcanic cone is an elevation produced by a deposit of substance ejected from a crater.

SYSTEM IN EARTH'S RELIEFS AND FEATURE-LINES. *Dana, pp. 23-38.*

Dana has been chief student of this subject and has given it undue prominence here. Read especially "Law of the System," p. 23, and "Recapitulation," p. 37. Great exception to general N. W. and N. E. trends is the Indo-European mountain system which trends E. and W.

ATMOSPHERIC CURRENTS. *Dana, p. 43.*

These give us key to oceanic currents and are therefore taken up first. If we had no atmosphere of air, we should have one of steam as a result of the sun's heat

which is sufficient to melt 8000 cu. mi. of ice, daily. Were there no transportation of heat, the temperature of the tropics would be perhaps 150° and that of the poles — 50° F. This would leave but a narrow belt where life could exist and it would probably be kept off there by furious winds. But since air is easily penetrated by direct heat and holds that which has entered it, lower air at Equator becomes very much warmed, and rises, causing an inflow of cooler air from poleward regions, to balance which an outflow towards poles takes place in upper air. This would give north and south winds toward the Equator in the tropics. But as earth's rotation causes an effect like that of a turn-table, throwing moving bodies on its surface to the right of a direct course, these currents of air are thrown to right, and N. E. and S. E. wind produced, known as the Trades. But air is a very poor conductor of heat and acts to equalize temperature only in a secondary way.

OCEANIC CURRENTS. *Dana, p. 38.*

Trade winds blowing steadily over the oceans within the tropics toward N. W. and S. W. cause, by their constant brushing over the surface, strong currents in the same directions, which meet near the equator and flow out on a westerly course. If earth's surface were wholly water this current would simply follow the equator, but being broken up by continents, it is turned N. and S. and carries into Temperate and Polar regions vast quantities of heat.

Thus in Atlantic the equatorial current splits on C. St. Roque, and losing influence of trades, a great current is carried by its own inertia up the western shore and across the ocean to its northeastern shore, and on in part, into the Arctic Zone. A part of this great "Gulf Stream" returns along the coast of Europe, but much the greater part returns along the bottom of the ocean, as a slow, cold current. Dr. Croll has shown that the Arctic Zone gets

more from Gulf Stream than from sun directly, and many parts of the earth are made habitable by warm currents. Since Cape St. Roque is some distance south of equator, the No. Atlantic O. gets more than its share of the equatorial current. To this fact is due the climate of England and her history. Great Japan current of the Pacific does not send any branch into Arctic O. If Alaska were below the surface this would happen; and this may perhaps explain the former mild climate of Greenland.

Gulf Stream had long been known in a general way, but was first definitely studied by Benj. Franklin, though he never clearly published his results. First careful study of ocean currents was by Maury, who plotted them from study of a large series of ship's logs. He believed them caused by greater height (17 ft.) of water at equator than at poles, due to its expansion from greater temperature at equator. Dr. Croll has shown that this gradient is incompetent to produce the known results.

WAVES are also caused by winds, but are only undulations not implying motion of translation. Their effect is to strike a blow.

CLIMATE. *Dana*, p. 43.

Land climate is result of interrelations of water and heat, and furnishes greatest extremes. Sea climate is much less variable. As an example of effect of absence of water, moon's surface is dead, without atmosphere or life. Only changes there are due to expansion and contraction caused by enormous daily extremes of temperature (perhaps 1000° to — 200° F.)

At the critical point of 32° F. the influence of water is wholly changed. Above, it is a liquid, readily absorbed and essential to life; below, it is a very slowly moving solid, fatal to life.

DISTRIBUTION OF FERTILE AND STERILE LANDS. *Dana*, p. 44.

II. LITHOLOGICAL GEOLOGY.

Rocks. *Dana, pp. 47, 62.*

This term is used to include all the materials of the earth's mass, excepting imbedded ice. Rocks give us the chief points in the study of the earth's physical history, while their contained fossils furnish much of the history of life.

They may be divided into two great groups, according to their origin.

MINERAL ROCKS are those which have originated solely from physical and mechanical causes, including by far the greater mass of rocks, the sandstones, granites, etc. According to structure they may be divided into two groups :

Fragmental rocks, formed of broken fragments of various rocks, are produced wholly by action of celestial forces working through water. These include sandstones, shales, etc. As soon as laid down these rocks become subject to action of terrestrial and celestial forces, for as new strata are laid down over them, the effect is to raise the temperature in lower strata in the same way as if a series of blankets were piled up over them, each new blanket serving to raise the temperature at any given point. This *blanketing* thus causes the lines of equal earth temperature (isogeothermal lines) to rise, and as a result of increased temperature and pressure the fragmental rocks become slowly changed to the second or *crystalline* form which is the state of rest of rock material.

Crystalline rocks include granite quartz, schists, etc. The effect of erosion on these rocks is to carry them back to the fragmental form, thus completing the cycle.

ORGANIC ROCKS owe their origin to physical and organic causes combined, and consist almost wholly of compacted remains of organisms. They include the limestones.

ELEMENTS IN ROCKS. *Dana, p. 48.*

Add to those enumerated by Dana, phosphorus, the relation of which to life will be noticed later.

DISTINCTIONS IN STUDY OF ROCKS. *Dana, p. 63.*

Note that specific gravity of rock is necessarily greater than that of water ; otherwise the earth's machinery must be stopped. Note carefully descriptive terms, p. 66.

Conditions and Structure of Rock Masses.**STRATIFIED CONDITION.** *Dana, p. 79.*

Stratified rocks are those arranged in layers, in whose deposition there has been an element of gravity. They may be formed in three ways : (1) by falling of matter through water to bottom ; (2) by falling of matter through air, as from a volcano ; (3) by lava flow from fissure or crater.

A *layer* (p. 81) is the structural unit in stratification ; it indicates the the continuation of certain forces for a time, followed by a change.

A *formation* consists of several or many strata of many layers each. It is less clearly marked than a stratum, which is not so readily distinguishable as a layer.

STRUCTURE OF LAYERS. *Dana, p. 82.*

Of structures originating in the act of deposition, the laminated and shaly, separated by Dana, are practically the same. Compound structure is due to the action of winds, waves, or currents. Strata formed by the wind are of uniform, fine material ; those formed by water may be of various materials. Strata formed by regularly flowing currents are of an uniform inclination, while those formed by tide currents or waves may be very uneven and broken.

Ripple marks (p. 84) indicate the presence, at time of their formation, of shallow water and a current, but not necessarily of a beach, since they are known to be formed in water 200 ft. deep. They are like marks formed by wind on sand or snow. How this action starts and what determines height and distance of ridges is unknown, though it may be a rolling motion of air or water. Both measurements are greater in water than in air.

Mud-Cracks are such as are commonly formed under a hot sun on muddy shores, and are often and easily fossilized by being filled with blowing sand or some other substance, and then buried under fresh mud.

Rain Drop prints are well preserved on some old beaches; from them we can often tell the direction of the wind during the shower, by the splash on the leeward side of the print.

Of structures of origin subsequent to laying down of strata:— the concretionary structure (*p.* 85) somewhat resembles the crystalline, but differs in that crystallization takes place in accordance with mineral species, at high temperatures, and results in definite geometrical masses, while concretion takes place more with reference to substance of matter deposited, at lower temperatures, and results in amorphous masses. Concretions often begin about an organic nucleus. Sometimes they are hollow or with interior filled with crystals. They often simulate animal forms, as in case of a form found in very old limestones in Canada and named *Eozoön Canadense*, whose true nature was for 20 years a subject of much dispute, many believing it to be the fossil remains of a very simple animal. Concretion and crystallization are the two great causes of metamorphosis in rocks, and are greatly aided by the presence and circulation through the rocks of waters having mineral matters in solution. A similar action is the taking on, by the constituents of rocks, of more of their own material from solutions, thus more firmly cementing the rock together. This is called interstitial metamorphosis.

All but the newest rocks are penetrated by breakage-lines (*p.* 88) usually in different directions, and irregularly placed.

These various planes cut up the rock and facilitate quarrying, where not so numerous as to render the rock worthless. The cause of formation of these “*joint-*

planes" is probably successive enormous pressures to which the rock has been subjected, each set of joint-planes being the index of a pressure at *right angles* to its direction.

Slaty cleavage (*p.* 89) is also caused by pressure, but differs from jointed structure in having its planes close together and in a single direction only. The rocks in which this structure occurs were formerly clayey mud which contains much mica in tiny particles. Pressure on this mud would bring the bits of mica more nearly parallel and start fracture-lines.

Movements of rocks on each other cause groovings, polishing, etc.

POSITIONS OF STRATA. *Dana, p.* 91.

Natural position of strata is horizontal, the tendency being to level irregularities, and, on an inclined surface, to form an incline of less angle. River-deltas, however, form beds which, at their further ends, have steep slopes.

Dislocations of strata caused by powerful forces are common, and of several forms. The simplest is the fold, which may be simple or modified by subsequent greater folds, or may be collapsed, that is, pressed together till there is no longer resistance to pressure and its sides meet, the whole fold falling over sidewise. The line of direction of the fold is called its *axis*. An upfold, with sides sloping away from a ridge is called an *anticlinal*; a downfold with sides sloping into a trough, a *synclinal*. The compass course of the axis of a fold is its *strike*, while the slope of its sides is the *dip*. These folds, etc., are negative results of the cooling of the earth's interior and consequent shrinkage and packing of the crust to accommodate itself to a smaller nucleus.

Faults are usually results of similar forces to those causing folds, and occur where rocks from their structure or from being thick-bedded, do not readily bend under pressure, but rend apart. Faults very commonly follow

joint planes, and may be of any size. In most cases there has been, in addition to rending, a slipping of rocks on opposite sides of the fault upon each other and this sometimes amounts to thousands of feet, bringing strata of very different age on to same level. Fault-planes may be located, like folds, by dip and strike. The portion of rock faulted out of place is usually wedge-shaped, and in a large majority of cases the strata have been pushed in the direction indicated by the point of the wedge. Since a joint-plane is commonly a warped surface the result of slipping of rocks is often to form open spaces where sides fail to fit closely, and many mineral veins have originated in this way. Another form of fault is caused by splitting of rock mass from shrinkage, forming "Gash-cracks."

Even the hard rocks are fluid to sufficiently great pressure and may be shown to have been compressed so as to be increased many times in length, by distorted fossils found in them. These can be recognized when extended to three or four times their length, but beyond this become mere blurs. One of the hardest tasks of the Palaeontologist is the reconstruction of distorted fossils.

Great sources of error in study and practical estimation of strata are folding and faulting, by which a single stratum may be brought to surface at several points and so made to seem like so many strata. The geologist avoids error of this sort by carefully noting the thickness of seemingly different strata as well as the character and thickness of beds immediately above and below them. Similarity in these data indicates pretty surely the identity of what seem to be distinct beds.

Effects of denudation and conformable and unconformable strata are sufficiently treated in text (*pp.* 96, 100).

ARRANGEMENT OF STRATA. *Dana, p.* 101.

Means of determining the order of arrangement of strata

are several, but the most important is the study of their fossils. It was suggested 200 years ago by Dr. Hooke that it might be possible to "raise a chronology" from the study of fossils, but nothing was done until the beginning of the present century, since which time it has been shown by careful study of fossils that there have been many nearly complete changes in the organic life of the earth's, surface. This was long believed to be due to the sudden extinction of life and the subsequent creation of new forms; but it is now believed that at various times new forms have arisen from existing forms by rather rapid changes and modifications, though we cannot say what forces have determined these changes. The study of these organic remains enables us to identify layers or beds of the same approximate age, to study ancient climates from the distribution and limits of species, and to study the currents of the ancient seas, and from them continental lines, chiefly from remains of reef-corals which require food-bearing currents for their growth.

From these studies, materials are accumulating for a complete history of the ancient conditions and changes of the earth, since organic life, on account of its delicacy and impressibility, preserves for us in its remains, records of many important facts of which the rocks give no hint. But the old idea that similarity of species of fossils in two layers indicates identity of age must not be too much trusted since a given region of the globe may have had at one time a very similar fauna to that of another region at a very different geologic period. For instance, as we go away from Europe we find life differing more and more from the life of that continent, and find that the present fauna of N. A. much more closely resembles the Middle Tertiary fauna of Europe than that of to-day, while the present Australian fauna is very like that of Europe in the Jurassic period.

It should be noted that fossils "of the same age" may

represent organisms which lived thousands of years apart, but under similar terrestrial conditions, that is, in the same geologic period. Fossils of the same age or geologic period are said to belong to the same "*horizon*."

UNSTRATIFIED ROCKS. *Dana, p. 107.*

These rocks may be divided into three classes; (1) lavas which have flowed from craters; these sometimes present a stratified appearance from the superposition of successive flows, and on the other hand some bedded rocks have been so metamorphosed by heat as to resemble lavas; (2) lavas which have flowed between bounding walls of rifts, forming dikes; and (3) deposits from solutions in water, such as those of mineral matter in veins. To these may be added for convenience, glacial drift which owes its origin to cold, while those properly belonging here are the result of heat-action.

DIKES AND VEINS. *Dana, pp. 108-113.*

Both these formations originate as rifts or cracks in the rock, caused by faulting or otherwise, and usually following joint-planes which become filled by different mineral substance.

Dikes are formed of full width from the first. When a series of beds, with a rift, becomes greatly heated by the blanketing effect of strata lying above, and one bed, being more fusible than the rest, becomes melted, the effect is to at once force this molten material upward into the rift, with or without volcanic action, filling the rift and forming a dike, which usually does not extend to the surface and is not exposed until the overlying strata have been planed away, ages later. Dikes are usually vertical and often very irregular; they frequently intersect, when their relative ages can be made out.

Fissures not filled by dike-material are sure to be sooner or later, by slow process, filled with deposits from percolating water, forming veins. These fissures may be formed at first of their full width, but oftener they are

gradually spread by the force of deposition and crystallization of substances within; this is called interstitial growth. All substances are found in sea-water in some quantity, it is supposed. These are taken up by plants and animals, as for instance, lime salts by corals, mollusks and others; soda and potash by sea-weeds; and nearly all elements in minute quantity by various forms. When these plants and animals die and decompose, these elements become a part of the rocks. This may be termed the first concentration of the elements. When deeply buried in the rocks, where the water has a solvent power equal to that of the strongest acids, due to its great temperature and pressure and large proportion of CO_2 , these substances are dissolved and the percolating water becomes charged with them. Here we have the second concentration. If now we have a series of beds with one or more rifts or cracks running through them, we shall find this saturated water working downward through the permeable strata, which are bordered by impervious ones, until it reaches the rift, through which it will rise rapidly, depositing on the walls the substances held in solution, in the order of least solubility, and so forming veins of metals or other substances. The forces which cause constant percolation of water through the rocks are: (1) Gravitation; (2) Osmosis; and (3) its tendency to penetrate towards a centre of heat.

DYNAMICAL GEOLOGY.

(*Dana, Part IV, p. 605.*)

Energy from the celestial spaces as applied to the earth's surface may be divided into two classes:—the generalized, physical forms, the winds, currents, etc.; and the localized form, seen in organic life.

Life. *Dana, p. 606.*

An organic form may be defined as a form of matter which has the power of taking into itself matter from without, and of utilizing its material and *force*. The work of earth-building depends on the interaction of organic and inorganic forces. The tendency has been to belittle the influence of organic life in this matter, but it is true that hardly any existing rock would be in just its present condition, but for this influence. In crossing North America we are for more than half the distance on rocks which are largely the result of organic life, and it may even be said that our continent owes its present form to this really powerful agent.

ITS PROTECTIVE EFFECTS. *Dana, p. 607.*

The most important protective effect of vegetation is to protect soil and roots from the washing effect of rains. A ploughed field loses much of its loose surface-soil with every rainfall. As the vegetation depends for its nourishment largely on the soil, so it protects itself by holding the soil, and a given piece of ground depends for its soil on its vegetation. Thus the two are interdependent. Sea-weeds protect the rocks on which they grow by preventing the water left in the crevices from freezing at low tide and rending the rocks. Our salt marshes of the New England coast are not merely protected, but have been won from the sea by maritime plants, chiefly grasses, rushes, and sedges.

ITS TRANSPORTING EFFECTS. *Dana, p. 607.*

ITS DESTRUCTIVE EFFECTS. *Dana, p. 607.*

These are better called *Metamorphic* effects of life, in harmony with the modern idea of our world, that of change, rather than of destruction and death.

Decay effectually attacks only exposed surfaces of rocks. Roots in their growth split rocks and thus expose more surface for erosive action. A cubic foot of rock broken up into cubic inches has more than ten times as much

surface as if in a single cubical block. Thus plants help to make the soil they need. If the Colorado cañons were grown with vegetation, their vertical walls and sharp angles would be lost, from the rounding and eroding action due to the leverage of plant-growth.

Earthworms do a great work in changing the surface of the ground. Mr. Darwin has shown that they average 40,000 to each acre of arable soil; and these pass through their digestive systems for the sake of the organic matter it may contain, many tons of earth per year which is left at the surface of the ground, so that thus the surface is often completely changed. Thus, also, stones and small objects soon become buried and Mr. D. believed that even some of the rural churches of England had been undermined and caused to sink noticeably by earthworms. A similar action is going on, by worms, on the sea-floor. Ants also do a similar, but less extensive work.

After life is extinct, many organic forms have much effect. Many growing trees shed during their lives woody matter of twenty times their own bulk, yet there remain at the base, but a thin layer of vegetable mould, whose constituents are constantly being absorbed by rowing plants, while the great bulk of the constituents of the original wood has passed into the air and been more or less absorbed by plants, in the gaseous form. Thus the dust to which we return is but a transient passing stage between life and life.

ITS CONTRIBUTION TO ROCK-FORMATIONS. *Dana, pp. 608-626.*

These take place chiefly under water where decomposition is slow and imperfect. Here plant and animal remains become enclosed in the rocks as stored-up carbon, in form of coal, limestone, etc.

On land, one of the chief forms of deposit is the peat-bog. These are formed in small ponds which become gradually filled up by the growth of peat mosses.

Starting from the edge of the pond, these mosses, chiefly of the genus *Sphagnum*, grow out slowly into the pond, growing upward and dying below, and forming a tangled, closely matted mass, which holds water like a sponge. This water admits of but very slow decay of the dead moss, which gradually falls to the bottom and forms a layer of black mould, between which and the sheet of moss is a layer of water. But the growth of the moss increases the thickness and weight of the sheet, and finally it reaches the bottom, filling the basin. As the moss is very yielding, the growth always forms a very treacherous bog. In some bogs in Northern N. A. the *Sphagnum* may grow up a slope for a few feet, but in Europe are bogs which have spread hundreds of feet from the original edge of the pond. These are called *climbing bogs*. They sometimes become so filled with water in heavy rains as to burst and flood the surrounding country with black mud.

A peat-bog must have one of two fates. It may be quickly lowered beneath the sea and then buried under rock strata, to form a coal bed under influence of heat and pressure. If slowly sunk, it will be destroyed by wave-action. Or it may remain above the sea-level, and be finally drained by cutting down of surrounding land. Then the dried peat will decay and return its stored carbon to the air. As temperature of tropics causes more rapid decay, no important bogs or coal deposits are found there. Peat bogs and coal-deposits are often underlaid by thin strata of so-called "*infusorial earth*," which consists of remains of microscopic plants and animals which lived in the pond that preceded the bog.

In the sea, the less complete decomposition of plants and their different composition result in the deposition of carbonaceous shales. A large deposit of this sort in the Ohio valley represents an old Sargasso sea. It is very rich in coal-oil products and was quarried for distillation, before the introduction of bored wells.

Animals leave deposits of mineral matters taken up by them during life, especially carbonate and phosphate of lime, and silica. Phosphorus, though existing in such small quantity, is essential to the animal organism: it enters into the constitution of bone, and is intimately connected with the working of the nervous system; it is secreted especially by the King Crab (*Limulus*) and the Brachiopods. Carbonate of lime is secreted by many forms. It is deposited on the floor of the deep sea chiefly by the tiny Foraminifera which live at the surface and whose dead shells and tests are constantly raining down upon the bottom to add to the slowly growing deposit. But shallow water deposits are due to fixed animals, and especially to corals.

Rising from the sea-floor in the So. Pacific O. are many mountain-like masses with steep slopes, coming above the surface as ridges enclosing shallow basins of water. These are solid masses of carbonate of lime in the forms of coral skeletons, with living corals at the top, and are called coral islands or atolls. The sea is constantly wearing away these masses by its beating on the outside, while the basin or lagoon within is quiet, though connected with the ocean by one or more openings, usually on the leeward side. On the ridge above water is found a beach of white calcareous sand, and above a wind-piled heap of this sand covered with a vegetation chiefly of palms. On the outside of the reef where the sea beats strongest are found the dome-shaped corals which can withstand the waves (*Maeandrina*, *Astraea*, etc.); in more protected situations are the branched forms (*Madrepores*), while in the inner basins are many very delicate corals and other animals. The crevices and tide pools everywhere swarm with various forms of animal life suited to them.

Along the N. E. coast of Australia is a great wall of coral over 1000 mi. long and several thousand feet high, known as the Australian barrier reef.

These coral reefs and islands depend on a sufficiently rapid growth to counteract and to gain on the wearing action of the sea. Their existence depends on the possibility of the association of numbers of individuals in colonies and on the presence of currents bearing sufficient food and warmth ($70-75^{\circ}$ F.) to support these colonies in their growth and to supply the immense energy expended by them.

Atolls were at first believed to be formed by masses of coral growing on sunken craters of old volcanos, since corals cannot live at a depth greater than 100 feet. But dredging showed the whole mass of the cones to be composed of coral, and Mr. Darwin began to collect data concerning them. He found that, while most of the atolls enclose open lagoons, some of them have islands of volcanic rock in the centre, and in other cases the island is a mass of rock closely fringed by coral, without water between.

From these facts he deduced the now accepted theory of their origin, that they are coral-reefs which started about the sides of volcanos when they became extinct. As the sea floor slowly sunk carrying down the volcano, the corals grew upward until at last in many cases they alone remain to show the site of the old volcano, while in other cases its top remains as the island in the lagoon. This would indicate a slow and steady subsidence of the sea-floor, as a rapid one would quickly have carried the corals beyond their depth; and we have a good illustration of the normal subsidence of the sea-floor caused by the cooling of the earth's interior, and resulting in a decrease in the earth's diameter of one to three feet in one thousand years.

From old coral-reefs we can determine the set of ancient currents and from the latter, the conformation of land masses; so that fossil coral-reefs give us valuable aid in plotting the early geography of the earth.

Cohesive, Capillary and Gravitative Attraction.

COHESION AND CRYSTALLIZATION. *Dana, p. 627.*

Cohesion is very variable in rocks, and each rock mass has two elements of cohesion, that of the whole mass, and that of the units constituting the mass. But in a given rock, the cohesion is constant, though sometimes increased or decreased by the effect of crystallizing action. Crystallization acts only till its work is accomplished, a comparatively short time.

Some rock are very elastic and this quality usually increases with density. A species of rock known as *Ita columbite* and resembling sandstone, is frequently associated with gold-bearing rock. It is so flexible that the ends of a strip supported at the middle will drop, of their own weight, to a certain point, beyond which, however, they are rigid.

All rocks contract and expand under cold and heat, the amount varying for different rocks. This has to be taken into account in the construction of fortresses and is of much importance in Geology, when we consider the great extremes of temperature through which many rocks have passed.

CAPILLARITY. *Dana, p. 629.*

This has an important effect. On a beach the waves grind up the sand and pebbles much less than they would, were it not for the thin layers of water between the grains, which are held there by capillary action. During long and severe droughts, on salt marshes which have been reclaimed and brought under cultivation, there may be seen efflorescences of salt, brought up from considerable depths by capillary action. Roofing slates are artificially separated by pouring water upon the edge of a block, when it is drawn into the cleavage planes, which were before invisible.

GRAVITATION. *Dana, p. 630.*

This force appears in some way in nearly all motion on the earth's surface, though always in conjunction with other forces. The soil on sloping hillsides tends constantly to slip down. But the chief effect of gravity is to pull down rocks from cliffs or elevations. The "Diablerets" is an amphitheatre near the upper Rhone, on top of whose high vertical walls formerly stood five mountain peaks. The surface on which they rest is soft and slopes inward toward the amphitheatre. Two of these peaks have already leaped off and another will soon do so, having slipped down the slope to the edge. Several destructive falls of this sort have taken place in the Alps. Earthquakes greatly assist in starting an action which gravitation can continue and complete. An important work of gravity is the breaking up of rock masses and so assisting in soil-formation.

The Atmosphere. *Dana, p. 630.*

The atmosphere is interesting, because it is the mechanism through which celestial energy is applied to the earth's surface. All life is absolutely dependent on the atmosphere, aquatic forms depending on the air contained in the water. In keeping the water aërated, storms, which stir it up and cause breakers, are very effective.

The atmosphere is to be considered (1) as a reservoir and (2) as in motion. It is a reservoir of oxygen, hydrogen and CO_2 . Oxygen is taken from the air by all living things and by the oxidation of various substances; a small amount is returned by the reduction of oxides, but how the great bulk gets back is not clear. CO_2 is taken by all plants and is returned by decay and combustion.

The atmosphere in motion is the wind. Its greatest authenticated velocity is about 100 miles per hour, though its force much exceeds this in volcanic explosions or rock-falls. The light weight of the air makes its rending power very small; but on soft rocks, sand, driven by the

wind, often has considerable cutting power. Loose sand not held in place by vegetation, as on sea-shores and deserts, is often heaped into hillocks or "dunes." These start like ripple-marks (*v. p. 8.*) and often reach a considerable size. The wind is constantly being blown over the crest from the windward side of these dunes and so they gradually travel across country with the prevailing winds, sometimes overwhelming villages. In this way deserts often extend their limits and so the Sahara has encroached upon ancient Egypt, coming down in places nearly to the Nile.

Fine sand is sometimes carried long distances by the wind and finally deposited, the successive deposits forming, at length, a thick layer over the surface, as in the valley of the Hoangho in China. These, which have been but recently studied, are called "Loess" deposits.

Note.—In the study of Geology we must radically correct our preconceived notions of time and its duration. Our conceptions are based on successions of events and their impressions on the mind; but we must learn to appreciate the stability of inorganic forms and phenomena as compared with the momentariness of organic life, and that geologic time is not to be measured by human life or by the duration of all life.

In considering geologic time we must give up, if possible, our ideas of a beginning and an end, in order to appreciate its vastness.

Water. *Dana, p. 635.*

Water does a much greater work than the air. Its functions are of two sorts, that of *storage* and that of *applying energy*. The former includes its carrying power for heat and various substances; the latter includes its action in falling and is due to heat and gravity.

Substances carried by water may be in perfect solution, so as not to be affected by gravity, or they may be mechanically suspended so that gravity constantly tends to make them settle to the bottom.

Heat causes water to evaporate and rise in vapor to form clouds, in which form it has great energy of position and tends to fall in obedience to gravity. When it falls, it is as rain or snow, and the roles played by these two forms of water are very different. Rain which has fallen is either reëvaporated and reprecipitated or else it passes into the ocean through streams, and is there evaporated. By the rainfall of a country may be meant simply the number of times its water is evaporated and precipitated. Forests act as sponges to hold water which has fallen until it is again vaporized and so increase rainfall, but probably do not increase the amount of rain from the ocean on a region. Thus the complete circuit of water is from the clouds to the earth as rain, through the rivers to the ocean and thence back to clouds.

Water at high speed has great energy, whether in waves or current. The maximum speed of currents is about 10-12 miles per hour, and their carrying power increases as the fourth power of the speed.

Water above the sea level has energy of position which it tends to expend by running down to sea, growing less and less powerful as it approaches the sea level.

Rivers. *Dana, pp. 626-663.*

Water, falling as rain, partly penetrates the soil, as ground water, and partly remains as surface water. Of all this water streams carry away from 15% to 25%, the rest being evaporated. A basin of water, the evaporation from which exceeds the supply, becomes a salt lake or *dead sea*. The ocean is prevented from becoming so salt and alkaline by the action of its organic life.

The effect of a stream, (*p. 641*) as soon as it becomes permanent, is to channel out a bed and to cut and leach away its sides. By its action the surface of its valley is lowered about one foot in 5000 years on an average.

A stream always tends to increase its curves by building on to one bank and cutting away the other until, at last, a bow is formed, with a narrow neck; then the stream cuts through the neck and leaves its old bed around the bow. But a change like this necessitates the reconstruction of all the curves in the river below, since all the curves of a stream have a definite relation. Thus a stream slowly works over its valley, and successive maps of a system at different stages of its history would show very various courses, though each would have a certain relation to the others. The ratio of the leaching action of a stream to its downward cutting depends largely on the character of the bed; in the canon of the Colorado (*p.* 645) the leaching action is almost nothing, from the hardness of the rock, and the river has cut deep gorges, with nearly vertical sides.

The topographic effects of erosion (*p.* 551) are influenced by three factors: the hardness of the rock, the structure of the rock as to jointing, etc., and the attitude of the beds. The second of these determines the amount of rending of the rocks by the penetration and freezing of water. The third also often has much influence on the courses of streams, where there is a tilting of the beds. In such a case, where there is a soft stream lying between hard ones, the former is worn away by the water, and thus the hard layers above are undermined, and at last cave in, so that the bed of the stream gradually works away in the direction of the dip of the strata. Where water flows over folded strata, its cutting action is greatest on the ridge and least on the depressions. This is due to the looser and more open character of the rock on an anticlinal, and its compacted and solid character in a synclinal. These variations in hardness and dip of strata thus can produce infinite variations in details of mountains and rivers, and are of great influence in determining the relief of a region. The above con-

siderations may give us an idea of the wonderful elasticity in the course of a river, and show that the position of a stream at a given time is only temporary and is derived from all past conditions.

The pot-holes in the New England Mts. (*p.* 553.) are connected with glacial action. When the ice-sheet was retreating, near the end of the glacial period, it acted in many places as a dam to block up river-valleys and form great ponds which rose until they overflowed their water-sheds and poured over into the opposite valleys. The rush of these torrents over the ridges, during the time when their outlets were dammed by ice, was the cause of the formation of these pot-holes.

The transporting effects of rivers (*p.* 553.) vary much with the characters of their valleys and other conditions, the long streams carrying out much more material in proportion than the smaller ones. It was formerly believed that a large part of the sediments of rivers are carried far out to sea, but it is now known that sea-water has the peculiar effect of causing the precipitation of substances at a very rapid rate, so that little sediment is carried far beyond the mouths of streams. Substances not merely in suspension, but truly dissolved in water may be carried any distance. This deposition of sediments is important in enabling us to make out old river deltas, from the structure of the strata, which always show considerable woody matter and also cross bedding of layers of sediments. From the study of old deltas in connection with present geography, much can be learned of the rivers which formed them. Thus Gay Head, Mass. is part of the delta of a large river which once drained New England, and perhaps west to the Hudson River; and the Isle of Wight is formed by delta-deposits of the old Rhine, when Great Britain was a part of the continent of Europe.

